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Lifetime Analysis of Wireless Sensor Network Considering Stay time and Stay Location of the Sink Node

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Abstract

The lifetime of the Wireless Sensor Network (WSN) is directly dependent on the battery power of the sensor nodes. Efficient routing protocol/mechanism is requiredto improve the lifetime of WSN due to restricted battery power of the nodes. Hence examining the lifetime of the WSN is an interesting area of research in WSN. WSN can be static or mobile depending on the application requirements.The clustering based routing algorithms are efficient in terms of energy/power saving of the sensor nodes.In this paper, an efficient routing protocol in WSN is proposed. Here, the clustering algorithm is applied that divide the entire sensor nodes of WSN into several clusters and the mobility of the sink node is introduced. The sink node passes through the network area in its fixed path and stays there for a certain amount of time and location called as 'stay-time' and 'stay location' respectively to collect the data from the sensor nodes.It is observed from the results of simulation that the lifetime of WSN running the proposed protocol is considerably enhanced compared to the lifetime of WSN running LEACH protocol.

Keywords: WSN, Cluster Head (CH), mobility, stay-time, stay-location.

I. INTRODUCTION

Wireless sensor Networks (WSN) are spatially distributed collection of embedded sensor devices with networking capabilities.The sensor nodes are limited with data communication capability and energy supply. Since long range data transmission consumes more energy than the short range data transmission, energy efficient data communication is important in WSN. An emerging field of research, in contrast to the established one, is WSN with mobile sink node (mWSN). The mWSN consist of several static sensor nodes to sense data and at least one mobile sink nodes for data collection process. The mobile sink nodes travel around the sensing area and gather data from the sensor nodes. Mobile sink nodes can be equipped on various objects or animals, such as robots, vehicle etc. that are movable [1]. The applications of WSN e.g. in military, where the battlefield deployment of sensor nodes track and monitor enemy movement; in environmental pollution detection and monitoring etc. are tabulated in the cited references [2][3][4][5][6][7][8].

To optimize the hotspot issue caused by the static sink node, the idea of mobile sink node has been introduced as a solution to balance the energy utilization by the hotspot nodes. When the sink node traverses across the network area for data collection, the hotspot nodes also changes with time. Hence the amount of energy utilization by the sensor nodes is equally distributed among all the sensor nodes of the WSN which eventually helps to prolong the network lifetime. The deployment of the sink node can be classified as constrained trajectory and unconstrained trajectory. In unconstrained trajectory, the sink node has the freedom to travel around the network anywhere, but in constrained trajectory, the sink node is constrained to move to some fixed locations within the network area. The main objective is to route the data efficiently to the mobile sink node as it travels the network for data collection. The paper proposesan efficient routing algorithm based on clustering approach to enhance the lifetime of the WSN with mobile sink node moving in constrained trajectory with certain stay-time parameter. The proposed protocol is better than the standard LEACH protocol in WSN with respect to network lifetime.

The rest of the paper is organized as follows. Works related to WSN lifetime is presented in section II. The methodology proposed viz. the mobility model is described in section III. Section IV elaborates the simulation and analysis of the results vis-à-vis the LEACH protocol. Conclusion is presented in section V.

II. RELATED WORK

Research work related to the proposed work as well as study of WSN lifetime is presented in this section. LEACH [9] is the first energy efficient hierarchical routing protocol for WSN. LEACH uses clustering algorithm for reducing long distance data transmission to save energy utilization by the sensor nodes. In this process, the network is divided into different groups known as cluster and each cluster is ruled by a cluster head (CH) which is selected randomly based on its energy level. The entire sensor nodes sense and transmit the sensed data to the cluster head, where the CH aggregates and communicates/transmits the data to base station (sink). This reduces the energy consumption because data transmission process is performed by cluster head only. The authors in [10] have proposed a Multi Clustered Energy efficient Routing Algorithm (MERA) where the concept of multi-chain formation among the nodes is applied to maximize network lifetime by minimizing the distance between the sensor nodes and the sink node. In multi chain formation, each node is connected to one another to form a chain. Here, the sink node is kept stationary and the entire network area is divided into N number of clusters based on its distance from the sink node. These clusters are further partitioned into M number of clusters to reduce the gap between various nodes. The chaining process starts at the nearest node from the sink node since the sink node has knowledge about the positions of sensor nodes. The first node i.e. nearest to the sink node in a cluster will search for the next nearest node to itself within the cluster and it will be connected to that node. This process continues till all nodes are connected to each other through the first node within the cluster. All the nodes within the cluster will form a chain. The first node of a particular cluster is responsible for sending the aggregated data of other nodes connected to it. This process is applied to all $N*M$ clusters. Authors in [11] have proposed MIEEPB protocol. The MIEEPB is a multi-chain approach without clustering algorithm but adopted the sink mobility to achieve efficient utilization of energy by the sensor nodes. For data collection, the sink node travels along its fixed trajectory and stays temporarily for some time at stopover location in MIEEPB approach. The authors in [12] have presented the MERAM-C protocol where the sink node moves in a constrained path in a clockwise direction continuously in the network area for data collection from the clustered sensor nodes. The clustering method used in LEACH protocol and sink mobility in constraint trajectory along with certain stay time and stay location parameters is applied in our proposed work in this paper.

III. PROPOSED APPROACH

This section presents the proposed approach/model and it consists of sensor node deployment, energy model, clustering, mobility model and the proposed protocol. In WSN the parameter 'round' is used to measure the performance of the sensor network [9]. In each round, the sink node completes the data collection process from the CHs only once.

1. *Sensor Node Deployment:*

The sensor nodes are deployed randomly at fixed coordinates within the network area. All the sensor nodes are homogeneous having limited energy/power [9].

2. *Energy Model:*

The energy model described in [9] is followed in our approach which is considered as the first order radio model where, the radio dissipates E_{elec}= 50 nJ/bit of energyto run the transmitter or receiver circuitry and $€_{amp}$= 100 pJ/bit/m^2 for amplification of signal. Therefore, in order to transmit'*k'* bit data towards a receiver positioned at a distance 'd' the radio model will spend the energy given by equations (1) and (2) below.

$$E_{TRS}(k, d) = E_{TRS\_elec}(k) + \text{€}_{amp}(k, d) \quad (1)$$

$$E_{TRS}(k, d) = E_{elec} * k + \text{€}_{amp} * k * d^2 \quad (2)$$

The power required to accept *k* bit data at the receiver side is given by equation (3) and equation (4).

$$E_{RCV}(k) = E_{RCV\_elec}(k) \quad (3)$$

$$E_{RCV}(k) = E_{elec} * k \quad (4)$$

3. *Clustering Approach:*

The clustering algorithm applied in [9] is also followed in the proposed work, where in every round each sensor node in the network decides to be a cluster head or not for the current round. The user sets the percentage (*P*) of becoming a CH at the beginning of simulation program to calculate the threshold value T(n) using current/present round r as given in equation(5).The sensor node picks out a number q whose value lies between 0 and 1 at random.

$$T(n) = \begin{cases} \dfrac{P}{1 - P * \left(r \bmod \dfrac{1}{P} \right)} & if\ n \text{ €} G \\ 0 & otherwise \end{cases} \quad (5)$$

G indicates the set of nodes that never became cluster head in the last $\frac{1}{P}$ rounds.

T(n) and q values are compared. If q <T (n)),then that specific node will become the cluster head for the present round r. Applying the equation (5) it is certain that every sensor node will become a cluster head once within this $\frac{1}{P}$ round. During the first round (i.e. r = 1), there is an equal chance to become a cluster head by every node. The nodes that were cluster heads during round 1 will not be the cluster head for the next $\frac{1}{P}$ rounds. Hence, the chances of becoming a cluster head for other nodes to become a cluster head increases. The chances to be a cluster head become very high after $\frac{1}{P}$ - 1 rounds for other nodes that were not cluster heads in the past.

4. *Mobility Model:*

In the proposed protocol it is assumed that the sink node has inexhaustible amount of energy/power. The ability of the sink node to move within the network area helps to enhance the lifetime of the network. The sink node moves in a constrained path from one location to another location and stays there for a certain amount of stay-time temporarily at that stay-location. Stay-time is the duration of time interval for which the sink node stays at specific location till the completion of some specific rounds $r_i(i = 1, 2 \ldots 8)$to collect data from cluster heads. Stay-location is the position where the sink node makes a temporarily stopover for data collection. The sink nodes starts the data collection from the initial stay-location (20, 80) and stays at that particular location for some predefined stay time and then moves to another stay location and collects data from there. This process continues till all the stay locations are visited by the sink node. The fixed stay-locations for the sink node used in the proposed protocol are shown in figure 1.

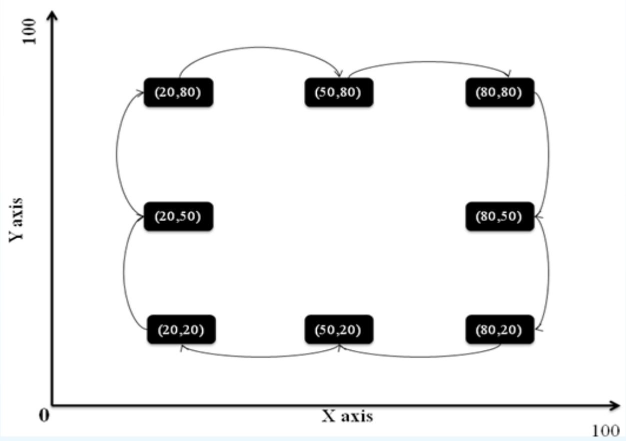

Figure 1: Stay-locations of the sink node.

5. *Proposed Algorithm:*

The total number of rounds considered in the proposed algorithm is 2000 rounds (i.e. $R_{max} = 2000$) and the number of stay locations adopted are 8 i.e. $L_i = 8$ ($i = 1, 2 \ldots 8$). The number of rounds 'r_i' to be completed in a particular stay location can be computed using equation (6).

$$r_i = \frac{R_{max}}{L_i} \qquad (6)$$

The sink node completes 250 rounds at each stay locations and the stay time spent at every stay locations is 27.34 seconds each. The steps of the proposed protocol are given below.

Algorithm:

```
for each sensor node do i = 1 to n, S (i) = (Xi, Yi)
    Install the nodes at random.
end for
for every round r = 1 to $R_{max}$, $R_{max}$ = 2000
    Based on a threshold value T (n), choose the cluster head.
    Configure the clusters as per chosen cluster head.
    for each cluster do
        Send the sensed data to the Cluster Head.
        Aggregate and forward the data to the sink node by Cluster Head.
    end for
    if completed round = = $r_i$
        Change the current stay-location of the sink to next stay-location.
    else
        Stay in the current stay-location till the completion of $r_i$ rounds.
    end if
end for
```

IV. IMPLEMENTATION AND RESULT ANALYSIS

The proposed protocol was implemented and simulated using MATLAB 7.12.0(R2011a)software configured on a laptop having Intel®Core™ I5 processor with 32 bit Windows®7 operating system and the results are compared with the LEACH [9] protocol. The parameters of simulation used were identical to the parameters used in LEACH protocol and are given in Table 1. Every sensor node possess same amount of energy i.e. $E_0 = 0.5$ J. The number of rounds in which the sensor node dies is noted down into three tiers i.e. 1%, 50%, and 100%. The sink node moves within the network area in a constrained trajectory and temporarily makes a stopover at stay locations with 27.34 seconds of stay time at each stay locations.On the other hand the sink node is kept stationary in LEACH protocol. Initially 100 alive nodes were considered and in each round the total number of alive nodes was recorded up to 2000 rounds.

Table 1: Parameters for simulation

Parameters	Value
Size of network	100 X 100 m^2
Total sensor nodes	n= 100
Energy of sensor nodes(Initial)	$E_0 = 0.5$ J
Size of packet	k = 4000 bits
Data Aggregation Energy	EDA= 5nJ/bit
Amplification Energy ($d>d_0$)	Emp=10pJ/bit/m^2
Amplification Energy ($d<=d_0$)	Efs=0.0013pJ/bit/m^2
Transmitter Electronics (E_{TRS_elec}) Receiver Electronics(E_{RCV_elec})	E_{elec} = 50 nJ/bit
Transmit Amplifier(ϵ_{amp})	100 pJ/bit/m^2

Figure 2 indicates the movement of the sink node from one position to another position during the simulation process. Number of rounds that was reached for first node (1%), half of the nodes (50%) and all of the nodes (100%) to die in both the protocols during simulation is depicted in table 2. Figure 3 exhibits the graphical representation for the number of dead nodes against number of rounds completed in the proposed protocol and the LEACH protocol. The sensor nodes are considered dead for the rest of the simulation once its energy level reached to 0. In the proposed protocol, the first node died at round 999, where as in LEACH protocol, at 795 round, the first node died. The last node died in LEACH protocol at round 1334 whereas in proposed protocol the last node died in 1599 round which shows that the lifetime WSN using the proposed protocol is of considerable length than the WSN using LEACH protocol. The graphical representation for the number of alive nodes against number of rounds that every sensor node finishes before dying is shown in figure 4. The lifetime of the WSN reached around 1300 rounds using LEACH protocol whereas in the proposed protocol, the lifetime of WSN reached around 1600 rounds.

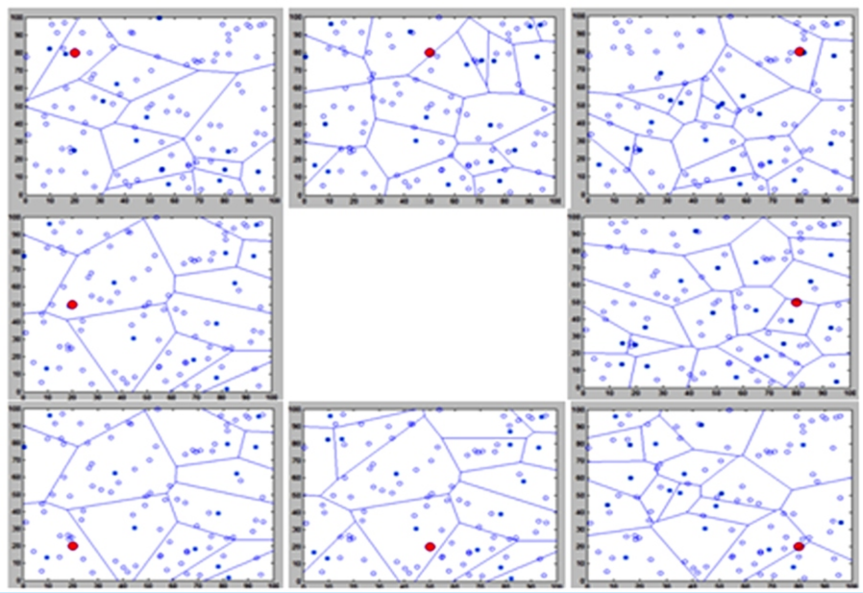

Figure 2: Movement of the sink node during simulation.

Table 2: Rounds completed when1%, 50% and 100% nodes dies

Protocol	**Rounds Completed** **First node died (1%)**	 **Half node died (50%)**	 **All node died (100%)**
LEACH	795	976	1334
Proposed Protocol	999	1213	1599

Figure 5 shows the graphical comparison between the number of packets transmitted to the base station per round in proposed protocol and the LEACH protocol. The total number of packets sent from cluster head to the sink node using LEACH protocol was 10967, on the other hand, the number of packets sent from cluster head to sink node was 25713 in the proposed protocol. In terms of performance, the proposed protocol is better than LEACH protocol.

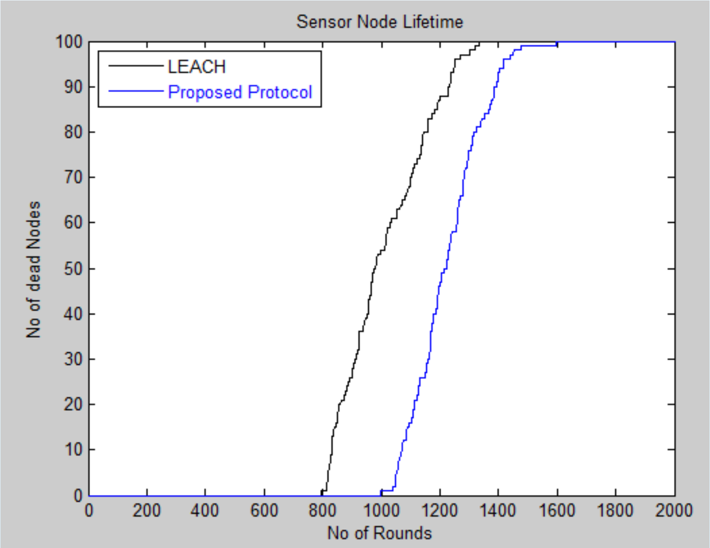

Figure 3: Comparison plot for the number of dead nodes in LEACH and Proposed Protocol.

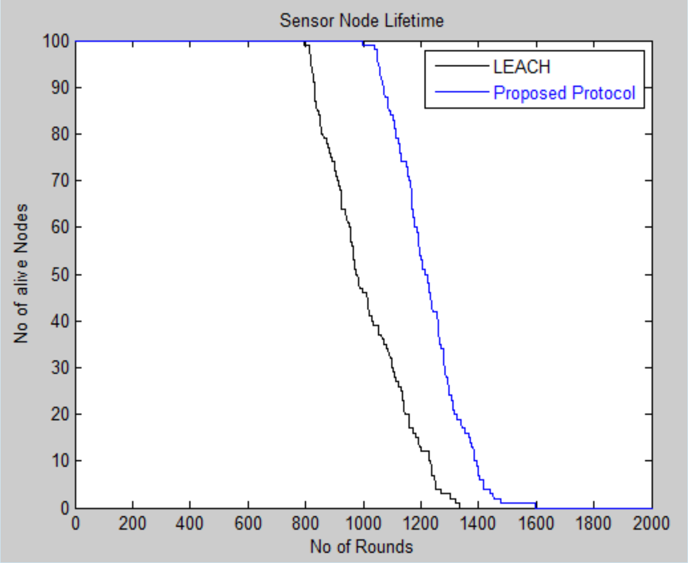

Figure 4: Plot for WSN lifetime comparison.

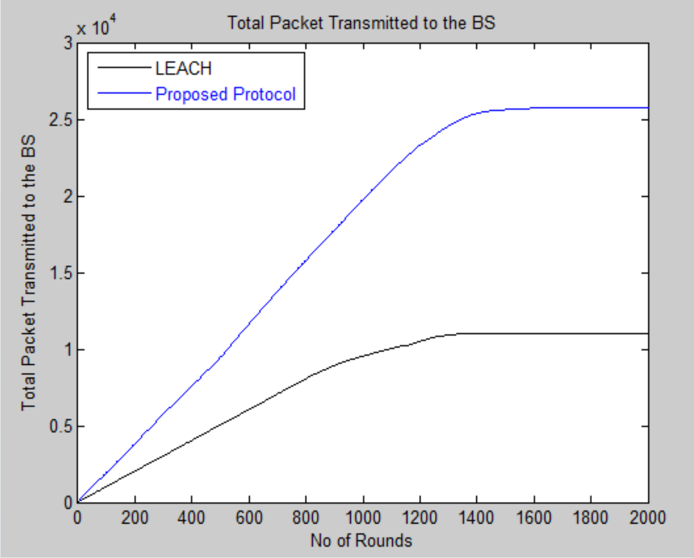

Figure 5: Comparison plot for total packets transmitted to the sink node.

V. CONCLUSION

In this paper a multi clustered routing algorithm along with enforcement of sink mobility to improve the lifetime of WSN is proposed. The main focus of this work is to incorporate the sink mobility so that the sink node moves across the network area for data collection. This leads to equal utilization of energy by the sensor nodes for data transmission. As a result the lifetime of WSN is enhanced.

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